agriculture

Article

Physico-Chemical Analysis of the Fruits and Consumer Preferences of New Apple (*Malus* × *domestica* Borkh) Hybrids Bred in Poland

Ewa Szpadzik *, Karolina Molska-Kawulok, Tomasz Krupa and Sebastian Przybyłko

Department of Pomology and Horticulture Economics, Institute of Horticultural Sciences, Warsaw University of Life Sciences (SGGW-WULS), 159C Nowoursynowska Street, 02-787 Warsaw, Poland; karolina_molska@sggw.edu.pl (K.M.-K.); tomasz_krupa@sggw.edu.pl (T.K.); sebastian_przybylko@sggw.edu.pl (S.P.)

* Correspondence: ewa_szpadzik@sggw.edu.pl; Tel.: +48-22-593-21-02

Abstract: Apples are the most important species in Polish fruit production, and their fresh fruit and processing products occupy a very important place in the European and world food economies. A natural process on the apple market is the replacement of older cultivars with new ones. Consequently, breeding work is being carried out all over the world to obtain new, attractive apple cultivars. In this work, four new apple hybrids obtained in the Department of Pomology and Horticulture Economics at the University of Life Sciences in Warsaw (WULS—SGGW), i.e., two red-skinned hybrids ('I'P' and 'TL') and two green-skinned hybrids ('GL' and 'LG'), were tested for their main physico-chemical characteristics after harvest and after storage, as well as for their consumer acceptability in a comparison with three popular cultivars in Poland ('Šampion', 'Golden Delicious', and 'Ligol'). The hybrids evaluated were differentiated in terms of the tested features. It was found that the fruits of the 'GL' hybrid had the highest firmness—both after harvest and post storage; it was also one of the highest-rated overall impressions by consumers among the cultivars tested (only 'Ligol' apples had higher scores). The hybrid with low fruit quality and low health-promoting properties at this stage of the study was 'TL', whose overall impression was also rated lowest by consumers. The study also showed that the content of bioactive compounds and antioxidant activity of apples can be higher in green-skinned cultivars compared to red-skinned cultivars.

Keywords: breeding; apple; fruit quality; storage; antioxidant capacity; polyphenols; flavonoids; consumer ratings

Citation: Szpadzik, E.; Molska-Kawulok, K.; Krupa, T.; Przybyłko, S. Physico-Chemical Analysis of the Fruits and Consumer Preferences of New Apple (*Malus* × *domestica* Borkh) Hybrids Bred in Poland. *Agriculture* **2024**, *14*, 1. https://doi.org/10.3390/agriculture14010001

Academic Editor: Grzegorz Lysiak

Received: 10 November 2023
Revised: 17 December 2023
Accepted: 18 December 2023
Published: 19 December 2023

1. Introduction

Apples (*Malus* × *domestica* Borkh.) are one of the most popular and widely produced fruits in the world. Their cultivars are highly valued for their flavours (sweet, sour, tart, and sweet–sour), nutritional value, as well as their ability to be used in a wide variety of ways [1,2]. Apples are an excellent source of vitamins (mainly vit. C, 2.3–31.1 mg/100 g DM), minerals (=ash 0.34–1.23%), dietary fibre (≈2–3% and pectin <50% apple fibre), carbohydrates, sugars (fructose, glucose, and sucrose), organic acids (0.2–0.8%), pectin, and water [3–8]. In addition to their nutritional value, they are also a valuable source of biologically active compounds, especially phenolic compounds, making them extremely beneficial to health [9]. The main phenolic compounds reported in apples are chlorogenic acid, epicatechin, procyanidins, phloretin, and quercetins, and their profiles depend on cultivar, environmental conditions, maturity stage, and storage time [10].

According to the USDA (US Department of Agriculture) [11], more than 80 million tons of apples were produced worldwide in 2022. Based on these data, China is the largest producer (about 45 million tons), followed by the European Union, which supplies approx.

12 million tons of apples, of which approx. 4 million tons are produced by Poland, placing it first in Europe and fourth in the world.

Currently, there are around 7500 apple cultivars worldwide, each with its own unique set of characteristics. According to PIORIN [12], in Poland, 74 apple cultivars are registered, of which only 8 dominate commercial production and cover approximately 80% of the orchard area. These are: 'Gala' (17.9%), 'Red Jonaprince' (15.3%), 'Golden Delicious' (15.2%), 'Idared' (11.2%), 'Šampion' (9.6%), 'Ligol' (8.5%), 'Red Delicious' (4.6%), and 'Jonagold/Jonagored' (4.3%). However, as some scientists report [13], the production of only a few commercially available varieties leads to a reduction in apple biodiversity. Additionally, it should be noted that apples are an extremely economically important fruit, which is why breeders around the world continue to develop new cultivars with improved characteristics [14]. Blažek [15] states that new additions to the list should have better fruit quality and be more resistant to disease than the cultivars currently grown. Today's breeding objectives are determined primarily by the market and consumer demands, and selecting high-quality apple cultivars is not easy. According to the researchers, apple fruit consists of both a large group of external and internal characteristics [16,17]. External characteristics include colour, shape, size, and the absence of defects. Internal quality, on the other hand, is flavour, texture, aroma, nutritional value, sweetness, acidity, and shelf life. Crunchy texture, juiciness, balanced sugar/acid ratio, and visual characteristics such as attractive red fruit colour, regular shape, and size are currently highly desirable attributes important in the choice of fruit [18]. The changing consumer preferences, the adaptation of cultivars to the principles of sustainable horticulture, and the changing climate are new challenges to be taken into account in today's breeding of new cultivars. But for consumers, however, the important attributes of apples are not only their high overall quality or sensory value, but increasingly also their nutritional value and health-promoting qualities. As consumers become more discerning in their choices and more aware of health and environmental issues, the evaluation of new cultivars is becoming not only a question of taste or overall appearance, but also of meeting changing expectations and values. Therefore, before being marketed, the fruit must have numerous requirements, both in terms of quality, with regard to external characteristics, as well as internal characteristics and health-promoting characteristics [19]. The evaluation of these characteristics is important, as they have a direct impact on consumer acceptance. In the evaluation of new apple cultivars, particular attention should be paid to the soluble solid content, acidity, and firmness of fruits, because these characteristics significantly determine whether an apple is sweet and crisp and thus whether it is attractive to customers. Although individual preferences vary, the ideal apple is one that harmoniously combines these traits, resulting in a fruit that is visually appealing, delicious, and nutritious [20,21]. It is noteworthy that a new generation of apple cultivars with improved fruit quality has hit the market recently (e.g., 'Pink Lady®, 'Kanzi®, and Jazz™). These cultivars are characterised, among other things, by better texture, higher soluble solids, or higher titratable acidity than current cultivars, such as 'Golden Delicious' or 'Jonagold', the two most commonly grown cultivars in Europe [22]. Nevertheless, consumer preferences have been found to vary according to geographical location and also between demographic groups in the population [23–26]. Sansavini et al. [27] divided apples into four groups corresponding to different consumer preference profiles. In the first group, they included 'American/European dessert apples' fruits with a nice shape, appearance, and colour (they are usually single-coloured), large size, and sweet-wine flavour. The second group included 'European refreshment apples', which were characterised by increased juiciness, tartness, and a uniform or two-coloured skin colour. The next group was 'Asian dessert apples', characterised by high sweetness and juiciness, firm flesh, low acidity, and long shelf life. The last group includes 'juicy, firm, and crisp (JFC) quality apples', which are an excellent combination of juiciness and crispness with genotypes with high sugar and acid content.

The purpose of the present study was a preliminary evaluation of four new apple hybrids in terms of the main physicochemical characteristics of the fruit, as well as their acceptance by the consumer compared to three popular cultivars in Poland ('Šampion', 'Golden Delicious', and 'Ligol'). We assume that the results obtained will help identify the most valuable hybrids in terms of fruit quality, which will then be subjected to further research. As a result, it will be possible to select the most valuable cultivars for registration.

2. Materials and Methods

The study was conducted in 2022 in the Department of Pomology and Horticulture Economics at the University of Life Sciences in Warsaw (WULS—SGGW). The research material consisted of fruits of the four new apple hybrids: 'Idared' × 'Prima' (red 'IP'), 'Granny Smith' × 'Ligol' (green 'GL'), 'Topaz' × 'Ligol' (red 'TL'), 'Ligol' × 'Granny Smith' (green 'LG'), as well as of the three apple cultivars, which are well known on the Polish market: 'Ligol', 'Šampion', and 'Golden, Delicious'. All fruit materials were obtained from 10 trees of each cultivar from the experimental orchard of WULS (SGGW), located in central Poland, in the area of Warsaw—Wilanow (Mazowieckie province: 52°09′38″ N 21°06′15″ E; 85 m a.s.l.). The soil in which we grew the plants was sandy–loamy, with a slightly acidic pH_{KCl} (6.0–6.5), and with 2.5% humus. The average annual temperature in the region is approx. 7.5 °C, and the total precipitation is 450 mm. The average temperature, rainfall totals, and relative air humidity for the 2022 vegetation season at the experimental location are presented in Table 1. The accurate meteorological data were obtained directly from a meteorological station located in the orchard where the experiment was set up.

Table 1. Meteorological conditions during 2022 vegetation season.

Month	Average Temp. (°C)	Precipitation (mm)	Relative Air Humidity (%)
March	5.21	53.4	71.15
April	7.21	35.6	65.94
May	13.79	39.2	74.26
June	19.21	121.8	77.25
July	19.07	48.4	79.39
August	20.98	59.2	84.97
September	11.49	35.2	92.34
October	10.16	24.0	94.96

All hybrids evaluated in the present experiment were obtained by Dr Cezary Piestrzeniewicz (breeder, then employee of the former Department of Pomology at WULS), who carried out crossbreeding and selection. Seedling selection was performed in 2003 and 2004. In 2013, the selected seedlings were grafted onto M.9 rootstock, while in 2015, the trees on M.9 rootstock were planted in the experimental orchard. Three other cultivars ('Ligol', 'Šampion', and 'Golden, Delicious') were planted in 2011 on M.9 rootstock. All trees grew at a distance of 3.5 m by 1.0 m, and they were managed in spindle form. An experimental orchard was applied according to the principles of integrated fruit production. The studied cultivars were harvested in September ('Šampion'—28.09) and October (all hybrids—5.10, 'Golden Delicious' 10.10, 'Ligol' 14.10), 2022.

In order to determine the optimum harvest maturity of the fruit, a starch test was applied, according to Blanpied and Silsby [28]. It was based on the reaction with Lugol's solution and assessed visually in comparison with the 10-point scale standards. The apples of all cultivars tested reached no. 7 on the starch index scale at the time of picking. After harvesting, apples from each tested cultivar were randomly divided into 3 groups, with 40 fruits in each group, as follows: 'group 1'—fruits to evaluate quality characteristics after harvest (i.e., physical characteristics, seed parameters, instrumental measurements, external colour, and antioxidant properties); 'group 2'—fruits placed in cold storage (2°C, relative humidity 90–92%) for instrumental evaluation after a storage period of 3 months (instrumental measurements, antioxidant properties); and 'group 3'—fruits intended for consumer assessment after a 3-month storage period.

2.1. Analytical Methods

- **Physical characteristics of the fruits:** The mean fruit mass (g) was calculated from a sample of 30 fruits for each replicate and measured on a TP 200 (OHAUS Europe GmbH, Nänikon, Switzerland) analytical balance. Then, we measured fruit height using a calliper gauge. The results were given in cm. In the next step, the width of the apples in two directions was measured at half-height with a calliper, and after averaging both results, the diameter of the fruit was obtained. The results were given in cm.
- **Seed parameters**: We counted the number of seeds in 30 fruits of each cultivar tested. The results were then averaged for each of the cultivars tested. In the next step, we weighed the seeds of each cultivar on an analytical balance TP 200 (OHAUS Europe GmbH, Nänikon, Switzerland). The results were also averaged for each cultivar. Then we calculated the mass of 100 seeds using mathematical calculations; the results were shown in grammes.
- **Characteristics of fruit quality after harvest and after storage**: All measurements were carried out in 4 repetitions for each cultivar, 10 apples per replication, both for apples immediately after harvest and for fruit after a storage period.

  The firmness (FF) was determined as the maximum force required to push the 11 mm Magness-Tylor probe penetrometer into the fruit (after skin removal) to a depth of 8 mm using an Instron 5542 tester (Instron, High Wycombe, UK). The results were expressed in Newtons (N) [29].
  The soluble solids content (SSC) was determined using the refractometric method at 20 °C in juice pressed from a sample of homogenised fruit using a refractometer (Atago, Palette PR-32, Atago, Co., Ltd., Tokyo, Japan), and the results were expressed in Brix degrees (°Bx) [30].
  Titratable acidity (TA) was determined according to Polish Standard PN-EN 12,147:2000 [31]. It was measured by an automatic titrator (Titro-Line 5000, Xylem Analytics Germany GmbH, Weilheim, Germany) using a solution consisting of 10 mL of apple juice (obtained in a juicer for the determination of SSC) and 100 mL of distilled water, which was titrated to pH 8.1 with 0.1 N NaOH.
  Furthermore, based on TA and SSC results, the TA/SSC ratio was calculated using mathematical calculations.

- **External colour of fruits**: Blush intensity was determined only for those apple cultivars that had blush, i.e., hybrids—red 'IP ', green 'GL', and red 'TL' as well as 'Ligol' and 'Šampion'. The basic peel colour was determined for those cultivars that had the visible peel colour, i.e., hybrids—green 'GL' and green 'LG' as well as for 'Golden Delicious' and 'Ligol'. We measured external colour with a Minolta CR-508i colourimeter (Minolta, Osaka, Japan) equipped with a 5mm measuring head, observer 10°, and illuminant D65. We calibrated the meter using the manufacturer's standard white plate. Measurements were made on the blush side of 10 apples per replication according to the CIE L*a*b* system, in which L* is a value in the range of 0 to 100 (dark-light), the parameter a* is a value in the range between 60 (green) and +60 (red) and the parameter b* is a value in the range between −60 (blue) and + 60 (yellow). We quantified the colour changes in the L*, a*, and b* colour spaces [32].
- **Antioxidant properties**: The analyses of antioxidant properties were evaluated separately in fruit peel and flesh. The fruit samples for assessing antioxidant value, taken separately from peel and flesh, were immediately frozen in liquid nitrogen and stored (−80 °C) after collection. All analyses were carried out for both fruit directly after harvest and for fruit after a storage period.

  Total polyphenol content was measured using the Marcel 330S PRO spectrophotometer (Marcel, Zielonka, Poland) according to the spectrophotometric method [33] with Folin–Ciocalteu reagent. according to the previously described method [34]. We extracted 5 g of fruit flash material and 1.25 g of peel separately, crushed in liquid nitrogen with 50 mL of 100% methanol. The extraction process was replicated twice by pouring the extracts into a 100 mL flask. One by one, 1 mL of extract was poured into a 50 mL flask, then 35 mL of H_2O, 2.5 mL of Folin–Ciocalteau reagent, and 7.5 mL of 10% $NaCO_3$ were added. The solution so prepared was supplemented with H_2O and incubated at 25 ± 2 °C for 20 min. The measurements were performed at a wavelength of 750 nm. As a standard, gallic acid was used at the following concentrations: 0.00, 0.05, 0.15, 0.20, 0.25, and 0.3 g/L. We calculated the polyphenol content using the following formula: (105.89 · absorbance2 + 25.318 · absorbance)/mass · 50. Total polyphenol content was expressed in milligrammes of gallic acid per 100 g^{-1} FW (fresh weight).

The analysis of the flavonoid content was performed according to the modified method of Marinova et al. [35] using a Marcel s330 PRO spectrophotometer (Marcel S.A., Warsaw, Poland) at 510 nm. We crushed 2.5 g of fruit flesh and 1.25 g of fruit peel separately in liquid nitrogen and used them to determine the flavonoids. The samples were mixed with 25 mL of 80% methanol and extracted for 15 min. The extractions were performed twice. In the next step, distilled water, 5% $NaNO_2$, 10% $AlCl_3$, and 1 M NaOH were sequentially added to the resulting samples at predetermined intervals. The flavonoid content was calculated using a standard curve (y = 1.86x), performed with quercetin solutions, and including the following concentrations: 0.00, 0.20, 0.60, 0.80, and 1.00 g·L. The total flavonoid content of the fruit was presented as mg of quercetin equivalents (QE) per 100 g^{-1} FW (fresh weight).

Antioxidant activity was evaluated according to the method of Saint Criq de Gaulejac et al. [36] using the synthetic radical DPPH (1,1-diphenyl-2-picrylhydrazine, Sigma-Aldrich, Poznań, Poland). The results were expressed in mg per g FW of ascorbic acid (AAE) (mg AAE·100 g^{-1} FW).

- **Consumer analysis of fruit after a 3-month storage period**: Acceptability was assessed by a blind panel test of 100 respondents who were all volunteers—students (women and men) aged 20–24. All participating judges are everyday apple consumers. The fruit was cut along the fruit axis into 8 pieces and placed on numbered plates to eliminate any suggestion of the cultivar's name in the sensory evaluation. The order in which the samples were presented was randomised for each judge. Mineral water was used as a palate cleanser between samples. The judges assessed all the samples and were asked to rate apple characteristics such as firmness, crunchiness, juiciness, sweetness, acidity, and overall impression acceptability according to a hedonic test (1—dislike very much; . . . ; 9—like very much). Point 5 indicates the neutral like/dislike level, and ratings below this point have been determined to be unacceptable by consumers.

2.2. Statistical Analysis

All the results, with the exception of the fruit consumer analysis, were analysed statistically via Statistica 13.3 (StatSoft Polska, Krakow, Poland) using one-way analysis of variance. The Newman–Keuls test was used to evaluate the significance of the differences between the means ($p \leq 0.05$). The table and figures also show the standard deviations.

3. Results

The results presented here represent only a preliminary analysis of the research, which will continue in future years.

3.1. Physical Characteristics of the Fruits

The fruits of the hybrids studied were significantly smaller—both in terms of mass (Figure 1a) and size, that is, height (Figure 1b) and diameter (Figure 1c)—than those of 'Šampion', 'Golden Delicious', and 'Ligol'. Taking into account the data on the average mass of the fruits, it was found that the fruit of the three comparative cultivars had a mass ranging from approx. 217 g ('Šampion') to approx. 246 g ('Ligol'). Among hybrids, on the other hand, the red 'IP' and green 'GL' hybrids were characterised by significantly larger apples (more than 184 g) compared to the green ‘LG’ hybrid, which had by far the smallest fruit (its weight did not exceed 150 g). When taking into account the height of the fruit, it was observed that ‘Šampion’ apples were significantly lower than ‘Golden Delicious’ and ‘Ligol’, whose fruit was characterised by the greatest height, i.e., over 7 cm. The height of the hybrids ‘IP’, ‘GL’, and ‘LG’ was comparable to those of ‘Šampion’ (all above 6 cm in height). The lowest height was found for apples of the red hybrid ‘TL’ (less than 6 cm), although they were only slightly lower than those of the hybrids ‘GL’ and ‘LG’. With regard to fruit diameter, it can also be seen that the apples of ‘Šampion’, ‘Golden Delicious’, and ‘Ligol’ were larger than the others (approximately 8 cm). Of the hybrids evaluated, only the red ‘IP’ had a slightly smaller diameter compared to the three comparison cultivars. On the other hand, it also proved to be the smallest cultivar among the tested cultivars in this case; the diameter of its apples did not exceed 7 cm.

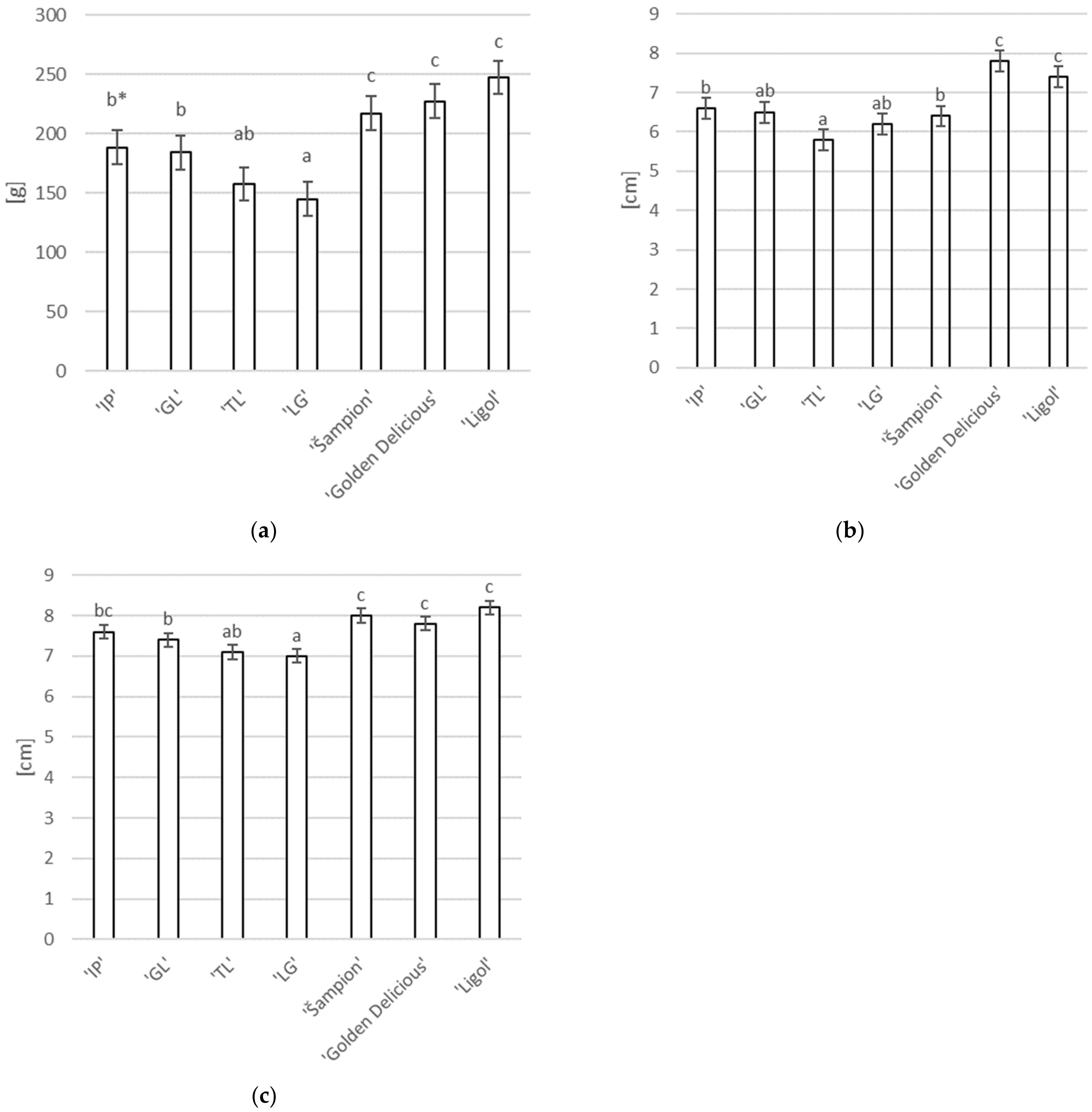
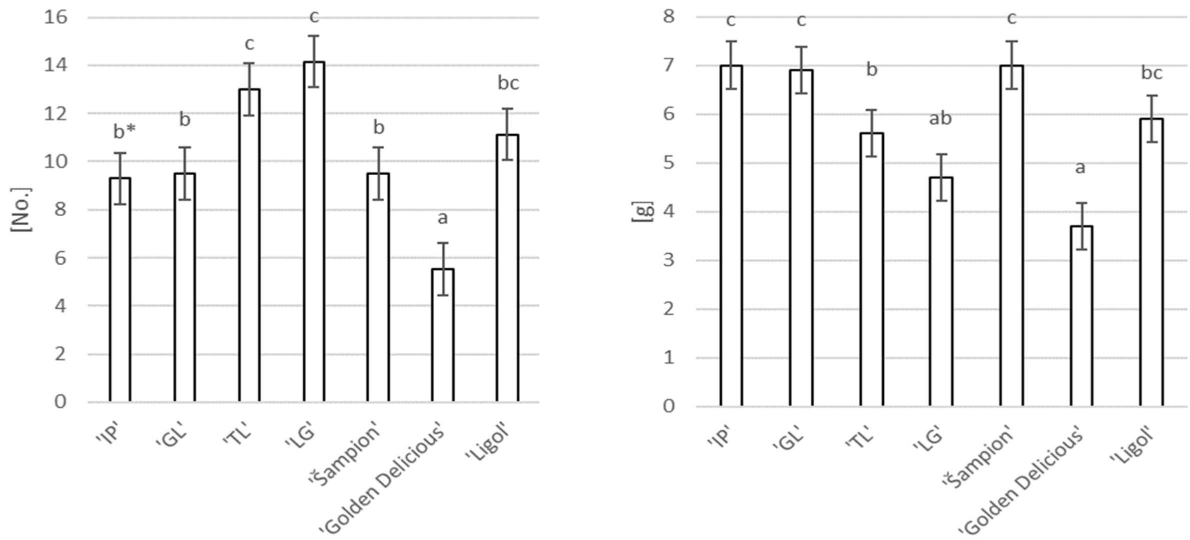


Figure 1. Physical characteristics of the fruits: (**a**) mass [g], (**b**) height [cm], and (**c**) diameter [cm]. * Values with different letters are significantly different.

3.2. Seed Parameters

The number and mass are traits that were largely determined by the cultivar (Figure 2). ‘Golden Delicious’ apples had the fewest seeds (on average 5.53/fruit) (Figure 2a), which were also characterised by the lowest mass of 100 seeds—3.7 g (Figure 2b). The highest number of seeds was found in hybrids ‘TL’ (13/fruit) and ‘LG’ (more than 14/fruit), although considering their mass, they were among the lighter of the cultivars tested. The hybrids ‘IP’ and ‘GL’, as well as the cultivars ‘Šampion’ and ‘Ligol’, were characterised by fruits with a similar number of seeds (above 9) and 100-seed mass (approx. 6–7 g).



(**a**) (**b**)

Figure 2. Seed parameters of apple cultivars: (**a**) number of seeds/fruit and (**b**) mass of 100 seeds, depending on the cultivar. * Values with different letters are significantly different.

3.3. Fruits Quality Characteristic after Harvest and after Storage

The analyses revealed that all the quality characteristics depended on the cultivar (Table 2). The hybrid ‘GL’ showed the highest firmness of the fruit, both after harvest (above 106 N) and after storage (above 83 N). The red hybrids ‘IP’ and ‘TL’ had high firmness after harvest (above 70 N)—although significantly lower than ‘GL’. Only slightly lower postharvest firmness compared to ‘IP’ and ‘TL’ was recorded for ‘LG’ (above 67) and Golden Delicious’ apples (above 68 N). A slightly lower post-harvest firmness was found for the cultivar ‘Šampion’ with approx. 64 N and the lowest for ‘Ligol’ with below 60 N. After storage, the lowest firmness was found in ‘LG’ fruit—below 40 N, as well as in ‘Šampion’ and ‘IP’, which had a firmness only slightly higher than ‘LG’.

The fruits of ‘Šampion’, Golden Delicious’, and ‘Ligol’ were characterised by the highest SSC after harvest—above 13°Brix (Table 2). Of the hybrids tested, only the red ‘TL’ had a comparable—although slightly lower—SSC after harvest. The fruits of the hybrid ‘GL’ were characterised by the lowest value of this trait (below 12°Brix). The SSCs of the cultivars tested were different after storage. Only the ‘Šampion’ apples had the highest SSC—above 15°Brix. Both green hybrids and the cultivar ‘Golden Delicious’ also had high SSC after storage—all above 13°Brix. The cultivar ‘Ligol’ had a lower SSC value after storage than before storage. The other cultivar whose SSC after storage was lower than after harvest was the red hybrid ‘TL’. Its SSC value was the lowest and reached approx. 11.5 after storage.

Table 2. Fruit quality characteristic after harvest and after storage depending on cultivar.

Cultivar	Fruit Firmness (FF) [N]				Soluble Solid Content (SSC) [Bx]				Titratable Acidity (TA) [%]				SSC/TA Ratio			
	PH		AS		PH		AS		PH		AS		PH		AS	
'IP'	70.02	±1.47 BC*	46.11	±0.41 AB*	12.10	±0.16 B	12.50	±0.20 AB	0.79	±0.02 E	0.57	±0.01 B	15.3	±0.53 A	21.25	±0.17 A
'GL'	106.07	±0.77 D	83.13	±0.32 D	11.30	±0.22 A	13.40	±0.10 C	0.43	±0.01 B	0.41	±0.01 AB	25.7	±0.99 B	32.68	±1.07 BC
'TL'	73.71	±1.95 C	48.74	±1.06 B	12.60	±0.25 BC	11.57	±0.10 A	0.67	±0.00 D	0.48	±0.02 B	18.7	±0.39 A	24.10	±0.90 AB
'LG'	67.65	±0.48 BC	39.75	±0.93 A	11.83	±0.12 AB	13.17	±0.15 C	0.46	±0.01 BC	0.35	±0.00 A	25.6	±0.79 B	39.34	±0.54 D
'Šampion'	64.37	±1.40 B	44.27	±0.76 AB	13.77	±0.12 C	15.18	±0.05 D	0.34	±0.02 A	0.41	±0.01 AB	40.6	±1.00 C	38.54	±1.20 CD
'Golden Delicious'	68.13	±1.41 BC	57.80	±0.24 C	13.80	±0.24 C	13.80	±0.40 C	0.54	±0.03 C	0.49	±0.03 AB	25.4	±0.90 B	27.55	±1.10 B
'Ligol'	59.37	±0.70 A	50.62	±0.88 B	13.30	±0.29 C	12.50	±0.40 B	0.46	±0.03 BC	0.37	±0.02 A	29.0	±1.50 B	33.78	±1.40 C

* Values with different letters are significantly different within a column. PH—postharvest. AS—after storage.

Statistical analysis after harvest revealed that the 'IP' hybrid had the highest TA of all cultivars (just under 80%) (Table 2). The 'TL' hybrid was also characterised by high fruit acidity, although it had a significantly lower TA compared to 'IP'. Fruit from 'Golden Delicious' had considerably lower TA than the above-mentioned cultivars—approx. 50%. Similarly to 'Golden Delicious', the value of the parameter in question was also characterised by the fruit of the hybrid and 'Ligol'. The lowest acidity after harvest was recorded in the cultivar 'Šampion '. After storage, on the other hand, the apples of the hybrids 'IP' and 'TL' were still found to have high acidity compared to the other cultivars, although statistically, the hybrid 'GL' and the cultivar 'Šampion' had similar acidity. On the other hand, a lower TA value relative to 'IP' and 'TL' was recorded in the hybrid 'LG' and the cultivar 'Ligol'.

Considering the SSC/TA ratio after harvest, it was found that the cultivar 'Šampion' had the highest value—above 40 (Table 2). A much lower SSC/TA ratio was recorded in both green hybrids, as well as in the cultivars 'Golden Delicious' and 'Ligol'—all below 30. The lowest value of the ratio in question was recorded in two red hybrids, below 20. After storage, all cultivars except 'Šampion' had a higher SSC/TA ratio than before storage. The highest SSC/TA value after storage was recorded for the green hybrid 'LG' apples—almost 40. The ratio was not significantly lower for 'Šampion' apples—approx. 38.5. A fairly high value for this ratio after storage was also found for the 'Ligol' and hybrid 'GL' apples. The lowest SSC/TA value after storage occurred for the red hybrid 'IP' apples—approx. 21.

3.4. External Colour of Fruits

3.4.1. Blush Intensity

Blush was visible on five of the seven cultivars tested, and its intensity, both in terms of the L* as well as 'a' and 'b', was a cultivar-dependent trait (Figure 3).

The 'GL' hybrids had the highest L* value— approx. 60, so it was found that their blush was the brightest among the other blushing cultivars (Figure 3a). The 'Šampion' apples also stood out from the other cultivars, with a significantly darker blush compared to the 'GL' hybrid, but with a significantly lighter blush than the other cultivars, with an L* value of approx. 48. The red hybrid 'TL' had the darkest blush (had the lowest L* value— approx. 40). In terms of the value of the L* parameter, both the 'IP' and 'TL' hybrids had a blush similar to that of the 'Ligol' cultivar.

However, when considering the 'a' parameter, it can be seen that the lightest blush, in the case of the 'GL' hybrid, was also the least coloured blush (Figure 3b). The 'a' parameter—indicating the colour from green to red—was the lowest in these apples—below 1. In contrast, this correlation was not confirmed for the cultivar 'Šampion', in which the rather light blush was also the most intensely coloured of the cultivars with blush—the 'a' factor reached a value of just under 30. The two red hybrids and the cultivar 'Ligol', were coloured red to a similar degree relative to each other ('a'—approx. 21–25).

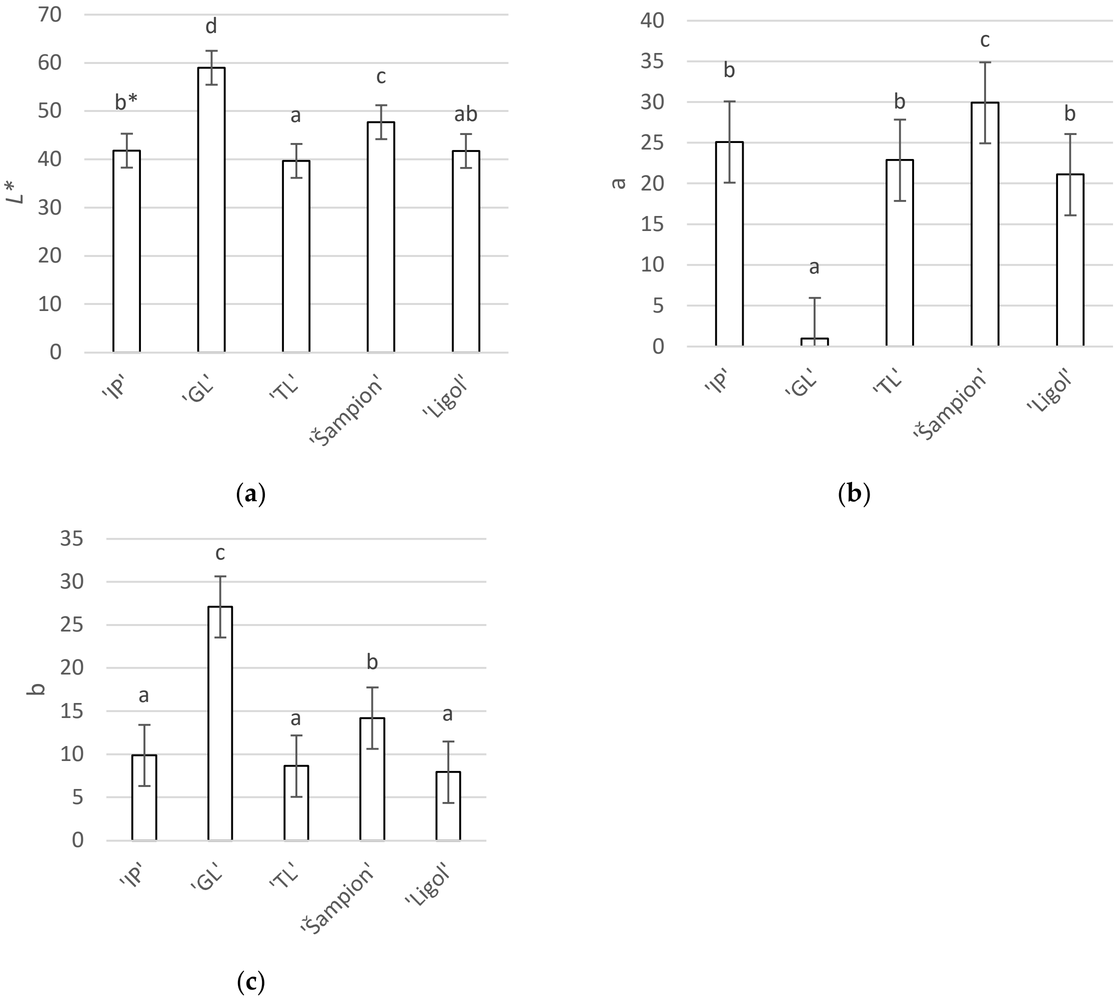


Figure 3. Blush intensity: (**a**) L* value, (**b**) 'a' value, and (**c**) 'b' value, depending on the cultivar. * Values with different letters are significantly different.

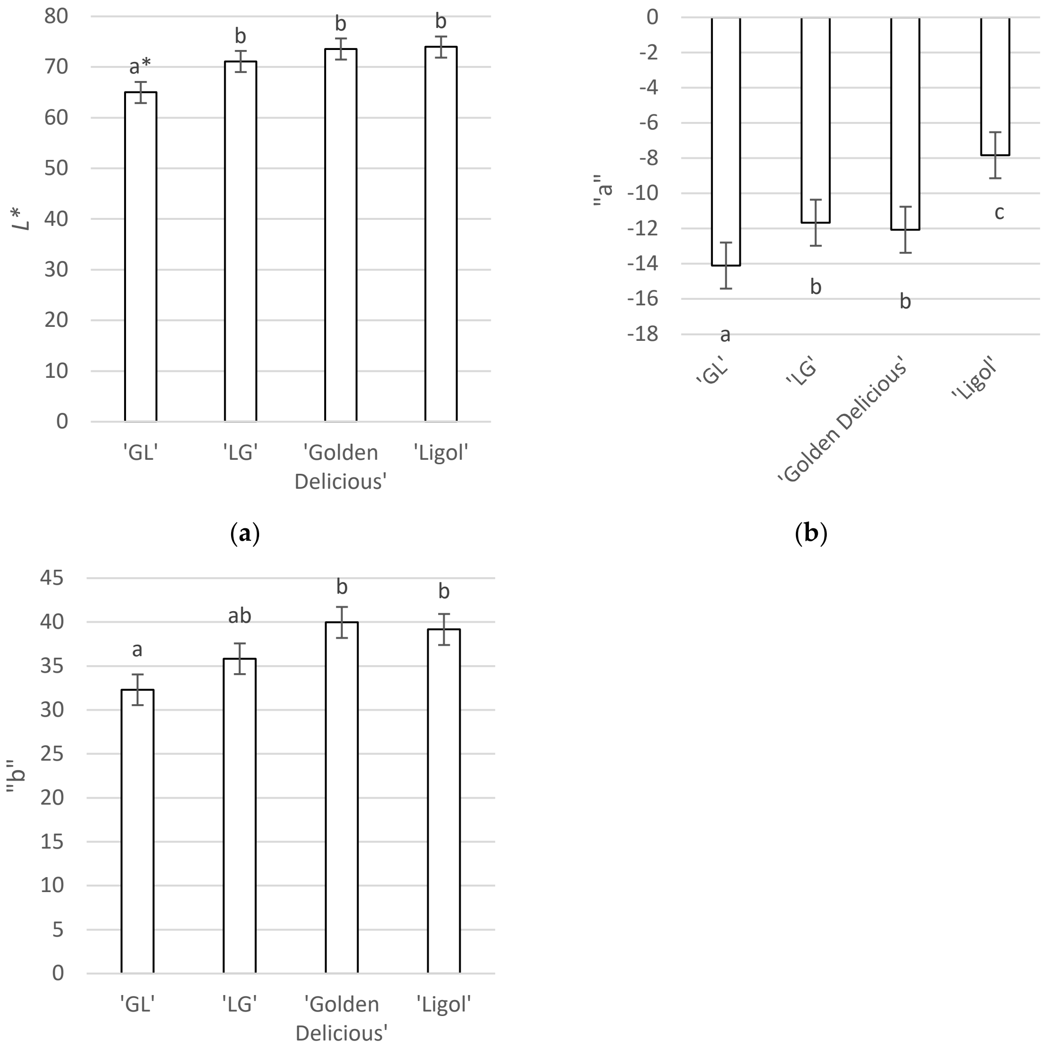
Taking the value of the parameter 'b', i.e., colour from blue to yellow, it can be seen that the hybrid with the brightest and least red 'GL' had the most yellow blush shade—above 27 (Figure 3c). The cultivar 'Šampion' demonstrated a significantly less yellow blush (factor 'b' value—approx. 14). In the apples of the other hybrids and the cultivar 'Ligol', the value of the parameter 'b' was significantly lower than in the two cultivars mentioned above, i.e., approx. 8–10.

3.4.2. Basic Peel Colour

Among all four hybrids and the three cultivars tested, only in two hybrids ('GL' and 'LG') and two cultivars ('Golden Delicious' and 'Ligol') was the basic peel colour measurable. In the analyses carried out, it was proven that, as in the case of blush colour, basic peel colour was also a characteristic determined by the cultivar (Figure 4).

It turned out that hybrid 'GL', which had an L* value below 70.0, had a significantly darker basic skin colour than the other hybrid and the other 2 varieties (L*—above 70). (Figure 4a).

It was also proven that the most intense green colour of the skin, expressed by the factor 'a', was observed in apples of the 'GL' hybrid (value of 'a'—approx. −14.0) (Figure 4b). A significantly less intense green skin colour was found in the second green hybrid and the 'Golden Delicious' cultivar (value 'a'—approx. 12). The apples of the cultivar 'Ligol' were characterised by the highest value of the parameter 'a' (approx. −7.8) and therefore the least intense green skin shade.



(**a**) (**b**) (**c**)

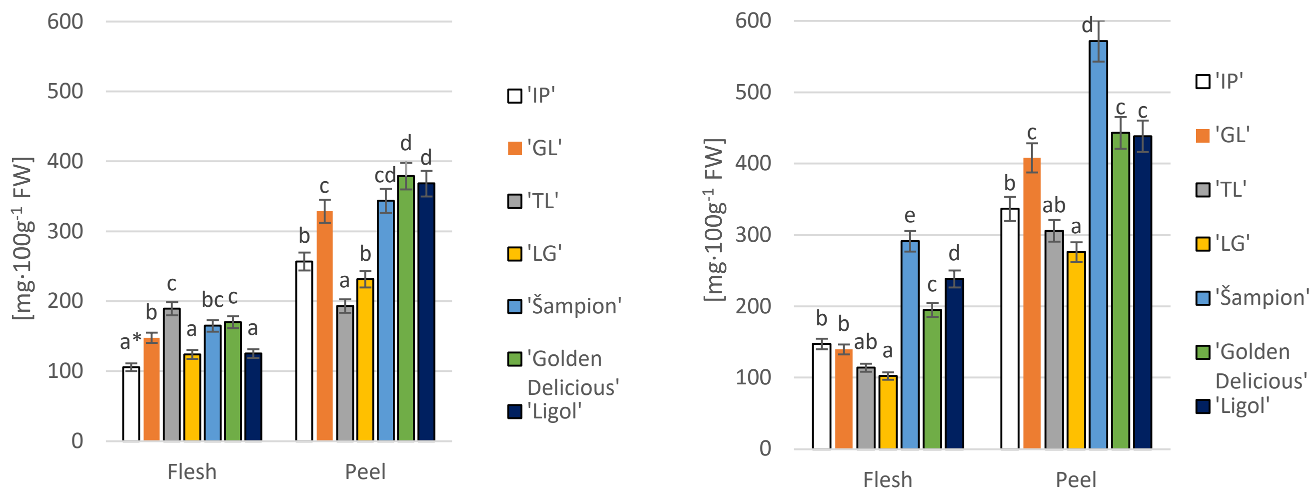
Figure 4. Basic peel colour: (**a**) L* value, (**b**) 'a' value, and (**c**) 'b' value, depending on the cultivar. * Values with different letters are significantly different.

It was also found that the basic peel colour of 'Golden Delicious' and 'Ligol' apples was significantly more yellow than that of 'GL' hybrid apples (Figure 4c). In the 'LG' hybrid, a value for the parameter 'b' of approximately 35.8 was observed, which showed that the intensity of the yellow skin colouration of these apples was similar to all other apples.

3.5. Antioxidant Properties

3.5.1. Total Polyphenol Content

Based on the analyses, it was found that the total content of polyphenols in the flesh and peel of the studied fruits, both before and after storage, depended on the cultivar (Figure 5). In general, it can be concluded that the content of polyphenols in the peel did not reflect the content of these substances in the flesh. Fruits with the highest content of polyphenols in the flesh directly after harvest were apples of the red hybrid 'TL'—approx. 190 mg·100 g^{-1} FW (Figure 5a). Only a slightly lower content of polyphenols was recorded in the flesh of 'Golden Delicious' apples—approx. 170 mg·100 g^{-1} FW. Meanwhile, the fewest polyphenols in the flesh were in the apples of hybrids: 'IP' and 'LG' and the cultivar 'Ligol'. On the other hand, a completely different correlation was noted in the peel of the fruit after harvesting. In this regard, 'Golden Delicious' and 'Ligol' cultivars had the highest content of the described compounds—more than 350 mg·100 g^{-1} FW. Slightly fewer polyphenols were in the peels of 'Šampion' fruit—approx. 343 mg·100 g^{-1} FW. The green hybrid 'GL' was characterised by only a slightly lower content of polyphenols in the peel (approx. 329 mg·100 g^{-1} FW.) compared to 'Šampion'. On the other hand, the lowest polyphenol content in the peel directly after harvest was characterised by apples of the 'TL' hybrid—despite the fact that this hybrid was characterised by the highest polyphenol content in the flesh.



(**a**) (**b**)

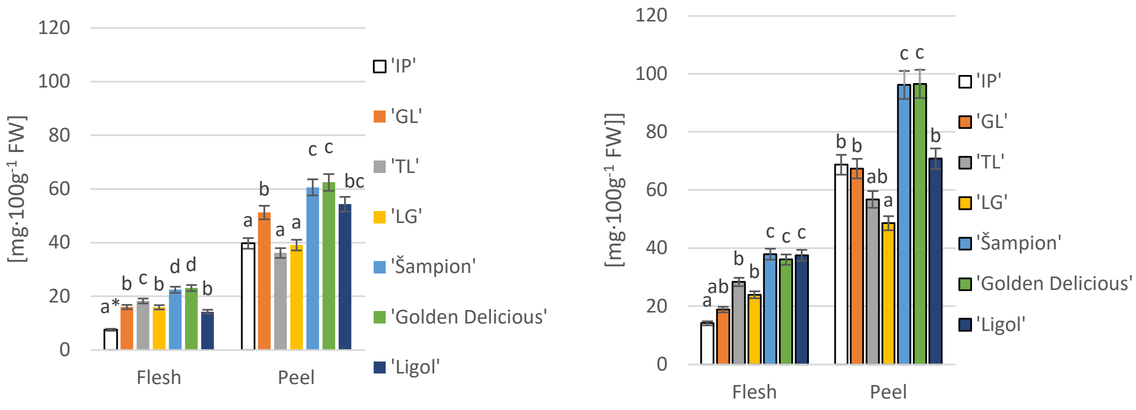
Figure 5. Total polyphenol content for flesh and peel: after harvest (**a**) and after storage (**b**), depending on the cultivar. * Values marked with different letters differ significantly within each part of the fruit (flesh, peel) at a given date of analysis (post-harvest, after storage).

Considering the total content of polyphenols after storage, a greater convergence than after harvest was noticed in the amount of studied compounds between the peel and flesh of the tested cultivars (Figure 5b). It was found that the least abundant in polyphenols both in terms of flesh and skin were apples of the 'LG' hybrid (approx. 102 mg·100 g^{-1} FW in flesh and approx. 276 mg·100 g^{-1} FW in skin). On the other hand, the cultivar with the highest content of polyphenols in both flesh and peel was 'Šampion' (approx. 291 mg·100 g^{-1} FW in flesh and over 571 mg·100 g^{-1} FW in peel).

3.5.2. Total Flavonoid Content

Similarly to polyphenols, the total flavonoid content of the flesh and peel, both before and after storage, also differed between the cultivars studied (Figure 6). The lowest flavonoid content in the flesh after harvest was characterised by the hybrid 'IP'—less than 8 mg·100 g^{-1} FW (Figure 6a). Also, in the peel of this hybrid, the content of the compound in question was one of the lowest; it did not exceed 40 mg·100 g−1 of FW. On the other hand, the highest flavonoid content was recorded in the flesh and peel of 'Šampion' and 'Golden Delicious' hybrids (above 20 mg·100 g^{-1} FW in the flesh and over 60 mg·100 g^{-1} FW in the peel). It is also worth noting that among the hybrids, 'TL' apples were characterised by a fairly high content of flavonoids in the flesh, while in the peel, 'GL' fruit had a relatively high content of the compound in question. Interestingly, the flavonoid content in the peel of the 'TL' hybrid—as well as 'IP and 'LG'—was among the lowest.

After storage, it was found that all hybrids had a significantly lower total flavonoid content in the flesh compared to the cultivars 'Šampion', 'Golden Delicious', and 'Ligol', in which the content was greater than 36 mg·100 g^{-1} FW (Figure 6b). The lowest content of flavonoids in the flesh after storage was observed in apples of the 'IP' hybrid (approx. 15 mg·100 g^{-1} FW). In the peel, the content of the compounds in question was significantly higher, with the highest flavonoid content observed in the 'Šampion' and 'Golden Delicious' cultivars—approx. 96 mg·100 g^{-1} FW. Significantly lower flavonoid content was observed in hybrids: 'IP and 'GL', as well as the cultivar 'Ligol'—approx. 70 mg·100 g^{-1}. However, apples from the 'LG' hybrid were the least rich in flavonoids, less than 49 mg·100 g^{-1}.

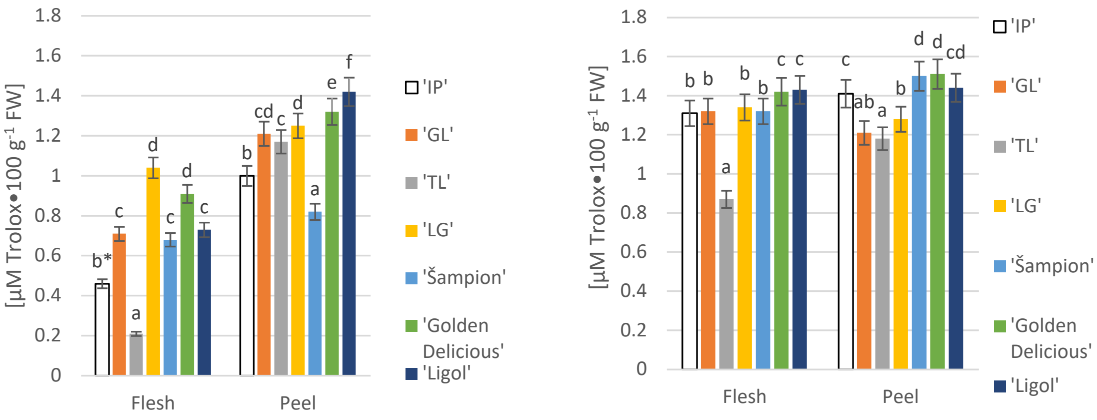


(**a**) (**b**)

Figure 6. Total flavonoid content for flesh and peel: after harvest (**a**) and after storage (**b**), depending on the cultivar. * Values marked with different letters differ significantly within each part of the fruit (flesh, peel) at a given date of analysis (post-harvest, after storage).

3.5.3. Antioxidant Activity—DPPH

The highest antioxidant activity in the flesh of the tested cultivars directly after harvest was recorded in the green hybrid 'LG' (above 1 µM Trolox·100 g^{-1} FW) and the cultivar 'Golden Delicious' (above 0.9 µM Trolox·100 g^{-1} FW) (Figure 7a). On the other hand, the lowest DPPH was found in the hybrid 'TL'— approx. 0.2 µM Trolox·100 g^{-1} FW. In contrast, these results are not reflected in the fruit peel. The highest antioxidant activity was observed in the peels of 'Ligol' apples— approx. 1.4 µM Trolox·100 g^{-1} FW. Fairly high, although statistically lower than in 'Ligol' DPPH in the peels, was found in 'Golden Delicious' (above 1.3 µM Trolox·100 g^{-1} FW). Both green hybrids had similar antioxidant activity to each other of more than 1.2 µM Trolox·100 g^{-1} FW, while the DPPH of the skin of the 'TL' hybrid was less than 1.2 µM Trolox·100 g^{-1} FW, and it was only slightly lower compared to that of 'GL'. The antioxidant activity in the peel of the red hybrid 'IP' was significantly lower than in the other three hybrids. On the other hand, the lowest value of DPPH in fruit peels after harvesting was recorded in the 'Šampion' cultivar—slightly above 0.8 µM Trolox·100 g^{-1} FW.



(**a**) (**b**)

Figure 7. Antioxidant activity (DPPH) for flesh and peel: after harvest (**a**) and after storage (**b**), depending on the cultivar. * Values marked with different letters differ significantly within each part of the fruit (flesh, peel) at a given date of analysis (post-harvest, after storage).

Post-storage analyses proved that the lowest DPPH in the flesh—as well as immediately after harvest—was characterised by the red hybrid 'TL'—below 0.9 µM Trolox·100 g^{-1} FW (Figure 7b). The flesh of the three other hybrids and the cultivar 'Šampion' was characterised by significantly higher DPPH (above 1.3 µM Trolox·100 g^{-1} FW). On the other hand, the cultivars 'Golden Delicious' and 'Ligol' had the highest post-storage DPPH activity in the flesh, above 1.4 µM Trolox·100 g^{-1} FW. However, when analysing the value of this trait in the peel after storage, it was found to be the highest in the cultivars 'Šampion' and 'Golden Delicious' (approx. 1.5 µM Trolox·100 g^{-1} FW). In the peel of the cultivar 'Ligol', only a slightly lower DPPH value was found, which was also slightly higher than that of the red hybrid 'IP'—approx. 1.4 µM Trolox·100 g^{-1} FW. The other hybrids were characterised by significantly lower antioxidant activity, while the lowest DPPH in the peel after storage period was recorded in the red hybrid 'TL', i.e., below 1.2 µM Trolox·100 g^{-1} FW.

3.6. Consumer Analysis of Fruit after Storage

Consumers rated individual characteristics, including the overall impression of the apples tested, differently and rather inconsistently (Figure 8). The red line on the figure indicates the point where the evaluated features were at a neutral like/dislike level—point 5. Thus, a feature rated below this point is considered unacceptable to consumers. The results show that for all the evaluated traits and overall impressions evaluated, none of the cultivars scored higher than 7.6. Similarly, none of the varieties scored less than a 3.1 in any of the categories. On a scale of 1–9, 7.6 was the highest average score given by participants, and 3.1 was the lowest average score given by participants. In general, it can be concluded that the highest-rated cultivar, both in terms of taste and overall impression, was 'Ligol'. Respondents gave all the tested attributes of this cultivar the highest marks, with the exception of acidity. The hybrid with the highest rating was the green hybrid 'GL', whose overall impression was rated only one point lower by consumers than that of 'Ligol'. The lowest rated in terms of overall impression were the red hybrid 'TL' apples, below acceptability, although their individual characteristics, i.e., firmness, juiciness, and acidity, were quite high. Interestingly, the overall fruit impression of the 'Šampion' cultivar was only slightly above the edge of consumer acceptability. On the other hand, apples of the 'Golden Delicious' cultivar were rated only slightly higher than 'Šampion' in terms of overall impression, and some of the assessed features of this cultivar were below the acceptable level. The overall impression of apples from the 'IP' and 'LG' hybrids was rated a little higher than that of the 'Golden Delicious' and 'Šampion' cultivars.

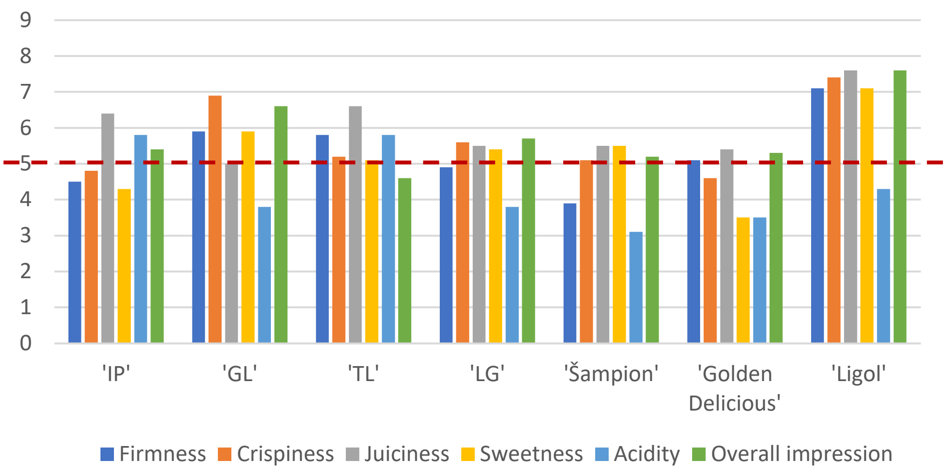


Figure 8. Consumer acceptance of evaluated characteristics. Red dashed line (point 5)—indicates the neutral like/dislike level, and ratings below this point have been determined to be unacceptable by consumers.

4. Discussion

There is no doubt that fruit quality is a key criterion that consumers consider when choosing a cultivar. Some researchers point out that insufficient fruit quality may be a limiting factor in fruit consumption [37,38]. The quality of apples encompasses a wide range of characteristics that collectively contribute to the overall impression of the consumer. These traits include appearance, texture, flavour, aroma, sweetness, tartness, juiciness, storage life, and nutritional value [39].

In our study, we evaluated the fruit quality of four new apple hybrids and assessed how they compare in terms of quality and consumer acceptability against three popular and well-liked cultivars in Poland, that is, 'Šampion', 'Golden Delicious', and 'Ligol'. The evaluation has considered the characteristics of the fruits that determine their market acceptability. Due to the fact that these fruits are often consumed after a storage period, the distinguishing qualities of the quality distinguishing features that usually change during storage (i.e., firmness, soluble solids, acidity, or antioxidant activity) were evaluated both directly after harvesting and after 3 months of storage. In addition, fruits after storage were also assessed by consumers in terms of features that they considered important. The measurements and analyses made it apparent that the hybrids studied differed in quality and health-promoting properties among themselves, as well as in relation to three comparative cultivars.

One of the first fruit characteristics to be evaluated in our experiment was fruit size (expressed in mass, height, and diameter) and the seed parameters (such as the number of seeds per fruit and their weight). Both parameters are largely genetic (varietal) [40]. Some scientists report a positive correlation between fruit size and seed number [41]. They also show that, in addition to fruit size, the average number of seeds per fruit affects various quality traits, such as the number of deformed fruits as well as fruit ripening. However, one should not always expect to find a large number of seeds in large fruit either. For example, triploid apple cultivars, despite their large size, do not have many seeds. Therefore, the size of the fruits is not always strongly correlated with the number of seeds, as was proved, among others, by Zisovich et al. [42] and Jemrić et al. [43]. However, there is no doubt that seeds play a huge role in fruit. They are important places for the production of hormones [44], especially auxins and gibberellins, which can increase fruit growth and improve mineral extraction. For apples, the number is also one of the factors that affect the calcium content [45]. Yet, it is known that calcium plays a primary role in determining the storage life of fruits [46,47]. In our research, the cultivars 'Šampion', 'Golden Delicious', and 'Ligol' were characterised by significantly larger physical parameters (fruit weight, height, and diameter) than the hybrids evaluated. The smallest fruits among the tested cultivars were characterised by apples of the hybrid 'LG'. Interestingly, it turned out that cultivars with the largest fruits had the smallest number of seeds, while cultivars with lower mass, height and diameter had more seeds. Furthermore, the smallest fruits of the 'LG' hybrid had the greatest number of seeds. Thus, these results support the point that the size of the fruit is not always determined by the number of seeds. Furthermore, in the study cited by Buccheri and Di Viano, the average number of seeds of 'Golden Delicious' was similar to the number of seeds in the same cultivar in our experiment and was also slightly above 5/fruit. It is worth mentioning that the size is determined by many factors, such as fertilisation, pollination, rootstock, crop load, agrotechnical treatments, or meteorological conditions during the growing season, among others.

Flesh firmness is one of the most important criteria for apple quality. Apples at harvest maturity usually have a fairly high firmness, but it decreases after storage, and consumers do not accept too soft, overripe apples [48]. However, consumer preferences in terms of firmness are not the same. The firmness value below which apples are considered unattractive is believed to be 44.2 N [49]. However, in the case of 'Gala', consumers prefer firmness above 55 N [21]. In the experiment carried out, all apples of the tested cultivars directly after harvest had a flesh firmness greater than 55 N. It should also be noted that the fruits of the hybrids were characterised by a rather higher firmness than those of the comparison cultivars. However, after the storage period, the firmness of the apples of the evaluated hybrids decreased to a greater extent compared to the other cultivars. While in hybrids and 'Šampion' the firmness during 3-month storage dropped by approx. 20–27 N, in 'Golden' Delicious' and 'Ligol' it dropped only by approx. 10 N. In the case of the hybrid 'LG', firmness dropped far below 44 N, so this allows us to assume that these apples lose their storability fast and should not be stored for more than 3 months. It should be noted that the hybrid 'GL' was characterised by impressive flesh firmness, incomparable to any other cultivar tested, both before and after storage, which in turn allows us to think that it may be quite attractive in the opinion of consumers.

The soluble solid content (SSC) and titratable acidity (TA) of apples can vary among different cultivars. Soluble solids content (SSC) includes mainly sugars (followed by acids, vitamins, and some water-soluble minerals), so the value of this trait is often identified with fruit sweetness [50]. Different apple cultivars have varying degrees of sweetness and tartness, and the balance between them is a key factor in consumer acceptability [20,51]. In the conducted experiment, cultivars directly after harvest have higher SSC than hybrids—only 'TL' achieved a similar, although slightly lower, SSC value. However, after the storage period, most cultivars had higher SSC values compared to those directly after harvest, which is in line with the results of the other researchers [52]. After the 3-month storage period, the two green hybrids were characterised by a relatively high SSC compared to other cultivars (only 'Šampion' exceeded them in this regard). Also, in terms of acidity (TA), both after harvest and after storage, the green hybrids had a lower percentage of malic acid compared to the red hybrids, suggesting that they would be perceived as less acidic. These results are reflected in the value of the SSC/TA ratio, which, as mentioned above, is a defining quality trait of apples. In both green hybrids, before and after storage, the SSC/TA ratio was higher than in the red hybrids. Directly after harvest, only 'Šampion' had a higher SSC compared to 'GL' and 'LG'. After storage, on the other hand, the value of this ratio was at a similar level or even higher than that of the comparison cultivars. It is worth noting here the consumer evaluation of the cultivars tested, as in many regards, consumers' impressions reflect the results of the instrumental evaluation of the apples after storage. As expected, the firmness of 'LG' apples, which was the lowest in the instrumental evaluation after storage, was also one of the lowest in the consumer rating and was below the level of acceptability. A similar situation can be observed for the 'Šampion' cultivar and the 'IP' hybrid, whose firmness was not high in both instrumental and consumer evaluations. On the other hand, the firmness of the hybrid 'GL', which performed best in this respect in the instrumental assessment, was also rated quite high by consumers; only the firmness of 'Ligol' apples was rated higher by consumers. Some similarities in the consumers' evaluation compared to the instrumental evaluation can also be seen with regard to the sweetness of the apples. Fruits with a higher SSC/TA ratio ('GL', 'LG', 'Šampion', and 'Ligol') were also rated higher by respondents in terms of sweetness. In contrast, the sweetness of apples with a relatively low SSC/TA ratio was also rated quite low in the consumers' evaluation. According to Pasquariello et al. [53], optimal sugar-to-acid ratio, juiciness, and firmness are some of the key characteristics positively influencing consumer acceptance. The results of our experiment seem to partially confirm this statement, as only in the case of the cultivar 'Ligol' were all the requirements mentioned achieved. For the apples with the highest firmness, the hybrid 'GL', consumers rated the firmness and sweetness well, but the juiciness was on the edge of acceptability. However, the overall impression of these apples performed well in the consumers' opinion. In the evaluation of the fruit, it is also worth noting the trait of crispness. This characteristic was rated highly by consumers only in the hybrid 'GL' and the cultivar 'Ligol'—that is, in those cultivars whose overall quality was rated the highest. It shows that crispness is also important for the consumer perception of the apples, which is also confirmed by reports by Jesionkowska et al. [54] and Symoneaux et al. [55].

Apple consumers also pay attention to its colour. The colour of an apple is often the first feature consumers look at. Different cultivars differ in peel and blush colour, and among new cultivars, there may be different shades and blush patterns that can be visually attractive. Colour can also indicate ripeness and freshness [56]. Of the four hybrids tested in this experiment, two of them, 'IP' and 'TL', were practically entirely covered with a blush of an intensity similar to 'Ligol', but much less intense than 'Šampion'. On the other hand, hybrids 'GL' and 'LG', originating, among others, from the cultivar 'Granny Smith', had practically no blush, although in the case of 'GL' apples, a small, very light, slightly orange shade could be seen. The basic peel colour of the 'LG' hybrid could be compared to 'Golden Delicious' and 'Ligol' apples. In contrast, in the 'GL' hybrid, the peel was darker and greener than that of 'Golden Delicious and 'Ligol'.

The content of bioactive compounds at harvest is considered as important marker for the internal quality of the fruit [57]. Such compounds are a source of dietary antioxidants that reduce the risk of many chronic disorders, including cancer [58]. Higher absorption of phenols also leads to a reduced risk of heart disease and lower cholesterol levels [59]. Apples are rich in components that are important for human health, such as polyphenols, organic acids, and microelements, but their chemical composition varies with different apple cultivars [60]. The content of the mentioned components is largely a genetic trait, depending on the species and cultivar [50]. In addition to genetic factors [61], bioactive compound content is influenced by a number of external factors, such as fruit maturity, exposure of fruit to sunlight, length, and type of storage or cultivation location [62–64]. The cultivars evaluated in this experiment also differed in their content of bioactive compounds. However, it should be noted that the content of the tested compounds was always higher in the fruit peel than in the flesh, which is in line with the reports of other researchers [65,66]. Usually, the content of individual compounds also increased during fruit storage, which is also confirmed in the literature [57]. It is difficult to conclusively indicate which of the tested cultivars was the most abundant or the poorest in polyphenols and flavonoids by considering flesh and peel separately, as well as the date of testing (post-harvest, post-storage). Overall, concluding the total content of polyphenols and flavonoids, it can be stated that the cultivars 'Šampion', 'Golden Delicious', and 'Ligol' were more abundant in these compounds compared to the hybrids tested. Among the hybrids, on the other hand, the green 'GL' was the most distinguished, in which the content of the compounds in question was usually higher in different parts of the fruit and on both analysis dates compared to the other hybrids. Thus, this shows that cultivars with green peel, basically no blush, do not have to be lower in content of polyphenols and anthocyanins than intensely coloured cultivars (such as hybrids 'IP' and 'TL'). A similar relationship can also be seen in the study by Kumar et al. [50], where green-peel cultivars had similar or even higher antioxidant content than red-peel cultivars. The same view is also presented by Kondo et al. [67], who believe that if the amount of anthocyanin in the skin is small, the anthocyanin may not contribute to the antioxidant activity in red cultivars. These results confirm the thesis that the content of bioactive compounds is a cultivar attribute [50,62]. In terms of antioxidant activity, the cultivars also varied somewhat among themselves. It was also evident that there was a large variation between the flesh and the skin of the fruit, as well as between the results from different analysis dates. Similarly, as in the case of polyphenol and flavonoid content, many different factors also influence antioxidant activity. The main compounds with antioxidant properties present in apples are polyphenols [68]. Thus, comparing the polyphenol content and DPPH value in individual cultivars, some similarities can be found, such as in the three comparison cultivars, in which DPPH was usually quite high, as was the polyphenol and flavonoid content. However, this dependence was not apparent in all cases in these cultivars. It should be noted that in some hybrids, such as 'IP and 'LG', in which the content of polyphenols, but also flavonoids, was not very high, the antioxidant activity was at a fairly high level. Moreover, for DPPH, the colour of the fruit peel did not affect its value. Green-skinned cultivars had similar, and often even higher, antioxidant activity than red-skinned cultivars. Confirmation of the above results can be found in the literature. The same view is also presented by Kondo et al. [67], who believe that it is possible that antioxidant activity in the fruit can be maintained by only a certain minimum polyphenolic concentration. Furthermore, they also claim that if the amount of anthocyanin in the skin is small, the anthocyanin may not contribute to the antioxidant activity in red cultivars. Therefore, cultivars with green fruit may have higher antioxidant activity relative to red cultivars. Considering the above, it can be concluded that, however, it is the cultivar factor that largely determines the antioxidant activity and, therefore, the health-promoting properties of a particular cultivar.

5. Conclusions

Taken together, we have shown that the four new apple hybrids differ from each other, as well as from the popular cultivars 'Šampion', 'Golden Delicious', and 'Ligol' both in terms of fruit quality and nutritional value, as well as consumer acceptance. However, on the basis of one research season, it is difficult to determine which of the hybrids studied will be the most valuable in terms of overall fruit quality. The most interesting at this stage of the research seems to be the hybrid 'GL' with the most intensely green fruit and highest firmness, which may indicate its high storability. In addition, the nutritional value of its fruit was also found to be quite high, and it proved to be the most acceptable by consumers among the hybrids (consumers rated the overall impression of 'GL' even higher than the cultivars 'Šampion', and 'Golden Delicious'). The fruits of hybrids 'IP' and 'TL' are completely covered with blush. However, the quality of their fruit was not very high, although 'IP' apples received positive consumer acceptance in terms of overall impression. 'TL' apples received the lowest consumer scores in this aspect; thus, it was the only cultivar tested whose overall impression was below the level of acceptability. The 'LG' hybrid had the smallest fruit with the lowest firmness and low content of bioactive compounds, but nevertheless performed positively in the consumers' evaluation.

Moreover, our research has shown that the content of bioactive compounds and antioxidant activity of apples is not always higher in dark-skinned cultivars. This is clearly a cultivar characteristic, and the content of polyphenols and flavonoids may not reflect antioxidant activity.

However, further research is needed to fully evaluate the fruit quality of the new apple hybrids.

Author Contributions: Conceptualisation, S.P.; methodology, E.S., T.K. and S.P. formal analysis, K.M.-K., E.S.; investigation, E.S., K.M.-K.; resources, E.S., S.P.; data curation, E.S., K.M.-K. and T.K.; writing—original draft preparation, E.S.; writing—review and editing, E.S. and S.P.; supervision, E.S., T.K. and S.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Atkinson, C. *Apples: Botany, Production and Uses*; Ferree, D.C., Warrington, I.J., Eds.; Experimental Agriculture; Cambridge University Press: Cambridge, UK, 2004; Volume 40, pp. 389–390. [CrossRef]
2. OECD. *Safety Assessment of Transgenic Organisms in the Environment, Volume 9: OECD Consensus Documents on the Biology of Crops: Apple, Safflower, Rice*; Harmonisation of Regulatory Oversight in Biotechnology; OECD Publishing: Paris, France, 2022. [CrossRef]
3. Karakasova, L.; Stefanoski, A.; Rafajlovska, V.; Klopceska, J. Technological characteristics of some apple cultivars. *Acta Hortic.* **2009**, *825*, 559–564. [CrossRef]
4. Hyson, D.A. A comprehensive review of apples and apple components and their relationship to human health. *Adv. Nutr.* **2011**, *2*, 408–420. [CrossRef]
5. Ferretti, G.; Turco, I.; Bacchetti, T. Apple as a source of dietary phytonutrients: Bioavailability and evidence of protective effects against human cardiovascular disease. *Food Nutr. Sci.* **2014**, *5*, 1234–1246. [CrossRef]
6. Koutsos, A.; Tuohy, K.; Lovegrove, J. Apples and cardiovascular health—Is the gut microbiota a core consideration? *Nutrients* **2015**, *7*, 3959–3998. [CrossRef]

7. Ploscutanu, G.; Elisei, A.M.; Buzia, O.D. Nutraceutical properties of apples and derived products (pomace, seeds, peels). *Rev. Chim.* **2019**, *70*, 934–939. [CrossRef]
8. Kidoń, M.; Grabowska, J. Bioactive compounds, antioxidant activity, and sensory qualities of red-fleshed apples dried by different methods. *LWT* **2021**, *136*, 110302. [CrossRef]
9. Hyun, T.K.; Jang, K.I. Apple as a source of dietary phytonutrients: An update on the potential health benefits of apple. *EXCLI J.* **2016**, *15*, 565–569. [CrossRef]
10. Pissard, A.; Fernández Pierna, J.A.; Baeten, V.; Sinnaeve, G.; Lognay, G.; Mouteau, A.; Dupont, P.; Rondia, A.; Lateur, M. Non-destructive measurement of vitamin C, total polyphenol and sugar content in apples using near-infrared spectroscopy. *J. Sci. Food Agric.* **2013**, *93*, 238–244. [CrossRef]
11. USDA (US Department of Agriculture). Available online: https://www.usda.gov/ (accessed on 15 September 2023).
12. Państwowa Inspekcja Ochrony Roślin i Nasiennictwa (PIORIN). Available online: https://piorin.gov.pl/ (accessed on 15 September 2023).
13. Donno, D.; Beccaro, G.L.; Mellano, M.G.; Torello Marinoni, D.; Cerutti, A.K.; Canterino, S.; Bounous, G. Application of sensory, nutraceutical and genetic techniques to create a quality profile of ancient apple cultivars. *J. Food Qual.* **2012**, *35*, 169–181. [CrossRef]
14. Storti, A.; Dalla Via, J.; Baric, S. Comparative molecular genetic analysis of apple genotypes maintained in germplasm collections. *Erwerb. Obstbau.* **2012**, *54*, 137–141. [CrossRef]
15. Blažek, J. Response to diseases in new apple cultivars from the Czech Republic. *J. Fruit Ornam. Plant Res.* **2004**, *12*, 241–250. Available online: https://www.inhort.pl/files/journal_pdf/journal_2004spec2/full2004-23Aspec.pdf (accessed on 15 September 2023).
16. Kellerhals, M.; Tschopp, D.; Roth, M.; Bühlmann-Schütz, S. Challenges in apple breeding. In Proceedings of the 19th International Conference on Organic Fruit Growing. 17.2., Publ. Föko, Weinsberg, Germany, 17–19 February 2020; pp. 12–18. Available online: https://ira.agroscope.ch/en-US/publication/43781 (accessed on 15 September 2023).
17. Musacchi, S.; Serra, S. Apple fruit quality: Overview on pre-harvest factors. *Sci. Hortic.* **2018**, *234*, 409–430. [CrossRef]
18. Colaric, M.; Veberic, R.; Stampar, F.; Hudina, M. Evaluation of peach and nectarine fruit quality and correlations between sensory and chemical attributes. *J. Sci. Food Agric.* **2005**, *85*, 2611–2616. [CrossRef]
19. Peng, Y.; Lu, R. Analysis of spatially resolved hyperspectral scattering images for assessing apple fruit firmness and soluble solids content. *Postharvest Biol. Technol.* **2008**, *48*, 52–62. [CrossRef]
20. Jaeger, S.R.; Andani, Z.; Wakeling, I.N.; MacFie, H.J.H. Consumer preferences for fresh and aged apples: A cross-cultural comparison. *Food Qual. Prefer.* **1998**, *9*, 355–366. [CrossRef]
21. Hoehn, E.; Gasser, F.; Guggenbuehl, B.; Casutt, M. Consumer demands on eating quality of apples: Minimum requirements on firmness, soluble solids and acidity. *Acta Hortic.* **2003**, *600*, 693–696. [CrossRef]
22. Zanetti, M.; Samoggia, A.; Young, J. Fruit Sector Strategic Management: An Exploration of Agro-food Chain Actors' Perception of Market Sustainability of Apple Innovation. *Sustainability* **2020**, *12*, 6542. [CrossRef]
23. Jönsson, Å.; Nybom, H. Consumer evaluation of scab-resistant apple cultivars in Sweden. *Agric. Food Sci.* **2006**, *15*, 388–401. [CrossRef]
24. Hampson, C.; Quamme, H. Use of preference testing to identify tolerance limits for fruit visual attributes in apple breeding. *Hort. Sci.* **2000**, *35*, 921–924. [CrossRef]
25. Richards, T. A discrete/continuous model of fruit promotion, advertising, and response segmentation. *Agribus. Int. J.* **2000**, *16*, 179–196. [CrossRef]
26. Seppä, L.; Railio, J.; Vehkalahti, K.; Tahvonen, R.; Tuorila, H. Hedonic responses and individual definitions of an ideal apple as predictors of choice. *J. Sens. Stud.* **2013**, *28*, 346–357. [CrossRef]
27. Sansavini, S.; Donati, F.; Costa, F.; Tartarini, S. Advances in apple breeding for enhanced fruit quality and resistance to biotic stresses: New varieties for the European market. *J. Fruit Ornam. Plant Res.* **2004**, *12*, 13–52. Available online: https://www.inhort.pl/files/journal_pdf/journal_2004spec2/full2004-1Aspec.pdf (accessed on 15 September 2023).
28. Blanpied, G.D.; Silsby, K.J. Predicting harvest date windows for apples. *Cornell Coop. Ext. Inf. Bull.* **1992**, *221*, 1–2. Available online: https://hdl.handle.net/1813/3299 (accessed on 15 September 2023).
29. Tomala, K.; Guzek, D.; Głąbska, D.; Małachowska, M.; Widłak, Ł.; Krupa, T.; Gutkowska, K. Maintaining the Quality of 'Red Jonaprince' Apples during Storage by 1-Methylcyclopropene Preharvest and Postharvest Treatment. *Agriculture* **2022**, *12*, 1189. [CrossRef]
30. Tomala, K.; Małachowska, M.; Guzek, D.; Głąbska, D.; Gutkowska, K. The Effects of 1-Methylcyclopropene Treatment on the Fruit Quality of 'Idared' Apples during Storage and Transportation. *Agriculture* **2020**, *10*, 490. [CrossRef]
31. *PN-EN 12147*; Soki Owocowe i Warzywne—Oznaczanie Kwasowosci Miareczkowej. Polish Committee of Standardization: Warsaw, Poland, 2000. (In Polish)
32. Stefaniak, J.; Sawicka, M.; Krupa, T.; Latocha, P.; Łata, B. Effect of kiwiberry pre-storage treatments on the fruit quality during cold storage. *Zemdirb.-Agric.* **2017**, *104*, 235–242. [CrossRef]
33. Waterhouse, A. Determination of total phenolics. In *Current Protocols in Food Analytical Chemistry*; Wrolstad, R.E., Acree, T.E., Decker, E.A., Eds.; John Wiley and Sons, Inc.: Hoboken, NZ, USA, 2002; pp. I1.1–I1.1.8. [CrossRef]
34. Szpadzik, E.; Krupa, T.; Molska-Kawulok, K.; Przybyłko, S. Fruit Quality and Contents of Some Bioactive Compounds in Selected Czech Sweet Cherry (*Prunus avium* L.) Cultivars under Conditions of Central Poland. *Agriculture* **2022**, *12*, 1859. [CrossRef]

35. Marinova, D.; Ribarova, F.; Atanassova, M. Total phenolics and total flavonoids in Bulgarian fruits and vegetables. *J. Univ. Chem. Technol. Metall.* **2005**, *40*, 255–260. Available online: https://journal.uctm.edu/node/j2005-3/Marinova.pdf (accessed on 1 September 2022).
36. De Gaulejac, S.C.; Provost, C.; Viras, N. Comparative study of polyphenol scavenging activities assessed by different methods. *J. Agric. Food Chem.* **1999**, *47*, 425–431. [CrossRef] [PubMed]
37. Briz, T.; Sijtsema, S.J.; Jasiulewicz, A.; Kyriakidi, A.; Guàrdia, M.D.; Van den Berg, I.; Van der Lans, I. Barriers to fruit consumption: Driving forces behind consumer behaviour. *Scr. Hortic.* **2008**, *8*, 7–18. Available online: https://edepot.wur.nl/605 (accessed on 15 September 2023).
38. Safdar, N.F.; Bertone-Johnson, E.; Cordeiro, L.; Jafar, T.H.; Cohen, N.L. Dietary patterns of Pakistani adults and their associations with sociodemographic, anthropometric and life-style factors. *J. Nutr. Sci.* **2013**, *2*, e42. [CrossRef] [PubMed]
39. Grunert, K.G. Consumer behaviour with regard to food innovations: Quality perception and decision making. In *Innovation in Agri-Food Systems: Product Quality and Acceptance*; Jongen, W.M.F., Meulenbeurg, M.T.G., Eds.; Wageningen Academic Publishers: Wageningen, The Netherlands, 2005; pp. 57–85.
40. Ramírez, F.; Davenport, T.L. Apple pollination: A review. *Sci. Hortic.* **2013**, *162*, 188–203. [CrossRef]
41. Buccheri, M.; Di Vaio, C. Relationship among Seed Number, Quality, and Calcium Content in Apple Fruits. *J. Plant Nutr.* **2004**, *27*, 1735–1746. [CrossRef]
42. Zisovich, A.H.; Goldway, M.; Schneider, D.; Steinberg, S.; Stern, E.; Stern, R. Adding bumblebees (*Bombus terrestris* L., Hymenoptera: Apidae) to pear orchards increases seed number per fruit, fruit set, fruit size and yield. *J. Hortic. Sci. Biotechnol.* **2012**, *87*, 353–359. [CrossRef]
43. Jemrić, T.; Babojelić, M.S.; Fruk, G.; Šindrak, Z. Fruit Quality of Nine Old Apple Cultivars. *Not. Bot. Horti Agrobot. Cluj-Napoca* **2013**, *41*, 504–509. Available online: https://notulaebotanicae.ro/index.php/nbha/article/view/9017/7661 (accessed on 15 September 2023). [CrossRef]
44. Luckwill, L.C.; Weaver, P.; MacMillan, J. Gibberellins and other growth hormones in apple seeds. *J. Hort. Sci.* **1969**, *44*, 413–424. [CrossRef]
45. Bangerth, F. Polar auxin transport as a signal in the regulation of tree and fruit development. *Acta Hortic.* **1993**, *329*, 70–76. [CrossRef]
46. Bramlage, W.J.; Weis, S.; Greene, A. Observation on the relation-ship among seed number, fruit calcium and senescent breakdown in apples. *HortScience* **1990**, *25*, 351–353. [CrossRef]
47. Brookfield, P.L.; Ferguson, I.B.; Watkins, C.B.; Bowen, J.H. Seed number and calcium concentration of "Braeburn" apple fruit. *J. Hortic. Sci.* **1996**, *71*, 265–271. [CrossRef]
48. O'Neil, C.E.; Nicklas, T.A.; Fulgoni, V.L. Consumption of apples is associated with a better diet quality and reduced risk of obesity in children: National Health and Nutrition Examination Survey (NHANES) 2003–2010. *Nutr. J.* **2015**, *14*, 48. [CrossRef]
49. Konopacka, D.; Płocharski, W.; Zwierz, J. Perception of apple quality in relation to texture attributes. *Acta Hortic.* **2003**, *604*, 443–448. [CrossRef]
50. Kumar, P.; Sethi, S.; Sharma, R.R.; Surender, S.; Supradip, S.; Sharma, V.K.; Verma, M.K.; Shashi Kumar, S. Nutritional characterization of apple as a function of genotype. *J. Food Sci. Technol.* **2018**, *55*, 2729–2738. [CrossRef] [PubMed]
51. Fellers, P.J.; Carter, R.D.; De Jager, G. Influence of the Ratio of Degrees Brix to Percent Acid on Consumer Acceptance of Processed Modified Grapefruit Juice. *J. Food Sci.* **2006**, *53*, 513–515. [CrossRef]
52. Jha, S.N.; Rai, D.R.; Shrama, R. Physico-chemical quality parameters and overall quality index of apple during storage. *J. Food Sci. Technol.* **2012**, *49*, 594–600. [CrossRef] [PubMed]
53. Pasquariello, M.S.; Rega, P.; Migliozzi, T.; Capuano, L.R.; Scortichini, M.; Petriccione, M. Effect of cold storage and shelf life on physiological and quality traits of early ripening pear cultivars. *Sci. Hortic.* **2013**, *162*, 341–350. [CrossRef]
54. Katarzyna Jesionkowska, K.; Konopacka, D.; Płocharski, W. The quality of apples—Preferences among consumers from Skierniewice, Poland. *J. Fruit Ornam. Plant Res.* **2006**, *14*, 173–182. Available online: https://www.inhort.pl/files/journal_pdf/journal_2006/Full18_2006.pdf (accessed on 15 September 2023).
55. Symoneaux, R.; Galmarini, M.V.; Mehinagic, E. Comment analysis of consumer's likes and dislikes as an alternative tool to preference mapping. A case study on apples. *Food Qual. Prefer.* **2012**, *24*, 59–66. [CrossRef]
56. Wong, R.; Kim, S.; Chung, S.J.; Cho, M.S. Texture preferences of Chinese, Korean and US consumers: A case study with apple and pear dried fruits. *Foods* **2020**, *9*, 377. [CrossRef]
57. Łata, B.; Trąmpczyńska, A. Relationship between apple bioactive compounds after harvest and their fate in cold stored fruits. *Acta Sci. Pol. Hortorum Cultus* **2008**, *7*, 89–99. Available online: https://czasopisma.up.lublin.pl/index.php/asphc/article/view/3696/2508 (accessed on 15 September 2023).
58. Alberti, A.; Zielinski, A.A.F.; Couto, M.; Judacewski, P.; Mafra, L.I.; Nogueira, A. Distribution of phenolic compounds and antioxidant capacity in apples tissues during ripening. *J. Food Sci. Technol.* **2017**, *54*, 1511–1518. [CrossRef]
59. Craig, W.; Beck, L. Phytochemicals: Health protective effects. *Can. J. Diet Pract. Res.* **1999**, *60*, 78–84. Available online: https://pubmed.ncbi.nlm.nih.gov/11551345/ (accessed on 15 September 2023). [PubMed]
60. Dobrowolska-Iwanek, J.; Gąstoł, M.; Adamska, A.; Krośniak, M.; Zagrodzki, P. Traditional versus modern apple cultivars—A comparison of juice composition. *Folia Hortic.* **2015**, *27*, 33–41. [CrossRef]

61. Unal, N.; Okatan, V.; Bilgin, J.; Kahramanoğlu, I.; Hajizadeh, H. Impacts of different planting times on fruit quality and some bioactive contents of different strawberry cultivars. *Folia Hortic.* **2023**, *35*, 221–231. [CrossRef]
62. Dhyani, P.; Bahukhandi, A.; Rawat, S.; Bhatt, I.D.; Rawal, R.S. Diversity of bioactive compounds and antioxidant activity in Delicious group of apple in Western Himalaya. *J. Food Sci. Technol.* **2018**, *55*, 2587–2599. [CrossRef] [PubMed]
63. Yoon, H.-K.; Kleiber, T.; Zydlik, Z.; Rutkowski, K.; Woźniak, A.; Świerczyński, S.; Bednarski, W.; Kęsy, J.; Marczak, Ł.; Seo, J.-H.; et al. A Comparison of Selected Biochemical and Physical Characteristics and Yielding of Fruits in Apple Cultivars (*Malus domestica* Borkh.). *Agronomy* **2020**, *10*, 458. [CrossRef]
64. Yilmaz, N.; Islek, F.; Cavusoglu, S.; Nečas, T.; Ondrášek, I.; Ercisli, S. Effect of exogenous essential oil treatments on the storage behaviour of apricot fruit harvested at different altitudes. *Folia Hortic.* **2023**, *34*, 1–13. [CrossRef]
65. Kistechok, A.; Wrona, D.; Krupa, T. Quality and Nutritional Value of 'Chopin' and Clone 'JB' in Relation to Popular Apples Growing in Poland. *Agriculture* **2022**, *12*, 1876. [CrossRef]
66. Sawicka, M.; Latocha, P.; Łata, B. Peel to Flesh Bioactive Compounds Ratio Affect Apple Antioxidant Potential and Cultivar Functional Properties. *Agriculture* **2023**, *13*, 478. [CrossRef]
67. Kondo, S.; Tsuda, K.; Muto, N.; Ueda, J. Antioxidative activity of apple skin or flesh extracts associated with fruit development on selected apple cultivars. *Sci. Hortic.* **2002**, *96*, 177–185. [CrossRef]
68. Duda-Chodak, A.; Tarko, T.; Tuszyński, T. Antioxidant activity of apples—An impact of maturity stage and fruit part. *Acta Sci. Pol. Technol. Aliment.* **2011**, *10*, 443–454. Available online: https://www.food.actapol.net/volume10/issue4/3 (accessed on 15 September 2023).